Editorials

The Future of Life Cycle Assessment

David Hunkeler[1]* and Gerald Rebitzer[2]

[1] AQUA+TECH Specialties, Switzerland
[2] Alcan Technology & Management, Switzerland

* **Corresponding author** (david.hunkeler@aquaplustech.ch)

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1 Background and Needs

Life cycle approaches, for the holistic identification and assessment of environmental impacts of goods and services[1], vary from qualitative decision support concepts and screening methods, to detailed inventory-based life cycle assessments (LCA). With their origins in, and links to, technology assessment (see e.g. OTA 1996), and first studies stemming from the late 1960s and early 1970s (Hunt and Franklin 1996), LCA has significantly developed over the past three decades. Life cycle assessment, indeed, represents a shift from pollution prevention (see Royston 1979) and gate-to-gate concepts, which focus on single facilities of industrial enterprises, to a view that incorporates the supply chain as well downstream processes related to a product. During this evolution, the main focus has been on methodological elaborations and building consensus on the general approaches and procedures. This important basis has lead to the creation of international standards such as ISO 14040 (1997), which is rather unique for an environmental assessment method. These developments, initiated and driven to a large extend by the Society of Environmental Toxicology and Chemistry (SETAC)[2] and related conferences and initiatives, are the basis for the application of LCA, which has the potential to be quite polyvalent. Indeed it can be a valid tool for integrating product-related decision making within industrial organizations and to gain insights into environmental hot spots, opportunities, and trade-offs, for example for policy processes.

The establishment of a, now quite well accepted, LCA methodology has been possible after years of work, between natural- and social-scientists, as well as engineers and practitioners (Marsmann 2000), and is currently being continued (Klüppel 2005). The resulting common understanding is essential for the widespread application of LCA, which in turn is an important component for making sustainable development operational. On the other hand, however, it is a fact that the application of LCA, and its integration into decision-making processes of organizations, is far from being standard practice. While there are some leading multinational firms, though also SMEs, who have embraced life cycle thinking and LCA, the application of LCA is still, often, limited to singular efforts and demonstration projects.

Stemming from this analysis, does the question 'Quo Vadis LCA?' seem relevant? From the point of view of the authors of this editorial, there are two complimentary and (partially) ongoing developments, which could provide a means to better exploit LCA's potentials, while maintaining its validity and scientific role.

- Development of **implementation processes** and related organizational approaches, which can close the gap between existing methodologies and tools and practical implementation
- Extension of the environmental life-cycle view to also address **economic and social aspects** within sustainability

2 Implementation of LCA and Related Approaches

LCA, while increasingly accepted, and more facile to perform due to databases and software systems (see e.g. Frischknecht et al. 2004, 2005, IKP/PE 2004, Pré 2004) faces some important challenges over the coming decade. This will include, among other topics, evaluations and comparisons of the results obtained through different variants of the methodology, issues related to uncertainty and data quality, as well as life cycle impact assessment sophistication. These topics, however, should comprise only one axis of development and refinement. Methods, operational procedures, and concepts for the implementation into business processes need more attention, and research, in order to enable the wide-scale exploitation of LCA's potential. Additional levels of sophistication, and new models, should not neglect the needs and the reality of decision making. Specifically, LCA needs to accept the responsibility to concretely contribute to sustainability; the pure provision of new scientific insights and ideas is not sufficient. Therefore, application-focused research dealing with questions on how to apply life cycle approaches and how to use them for business and other organizational processes should be strengthened and better valued, also from a scientific point of view. The thresholds for sustainability

[1] Goods and services or their utilities can be summarized under the term 'product' (WCED 1987)
[2] See www.setac.org

are vague and will likely require some time to define. However, even such limits are insufficient if not applied on a scale and with means which can move manufacturing, material, energy, transport, use and disposal choices, in both the micro- and macro-economies.

To achieve a more widespread applicability, LCA needs to expand its role in communication, and scientific journals have a role in this. The life cycle management (LCM) section of the International Journal of LCA (Heinrich and Klöpffer 2002) is part of this thrust. We seem, now, able to provide less jargon-based approaches and to clearly summarize and validate results, and to better identify limitations and constraints of life cycle concepts. However, we must also, as an LCA community, develop improved formats and procedures which are suitable, for instance, for sales and marketing, accounting, and product development teams. In short, LCA as a science has to overcome the, general, lack of support in the highest circles of academia. A fully developed LCA approach and associated cases should strive for implementation as the ultimate goal and not be limited to the use for publications[3].

This discussion is not restricted to LCA, but applies equally to life cycle approaches aiming at the other two dimensions of sustainability, which are addressed in the following Sections of this editorial.

3 Extension of the Environmental Life Cycle View to Economic and Social Aspects: Three Pillars of Sustainability

Sustainable development is a concept relatively simple to define, though difficult to quantify. Issues include the lack of metrics, as well as means to link microeconomic effects and local impacts and influences with macroeconomic or global parameters. While the latter can be estimated, for example for some environmental issues, in terms of average temperatures and extreme climatic events (Biswas et al. 1998, Allenby et al. 1998), linking product-based impacts to global parameters remains challenging. Perhaps more significantly, the assessment of sustainability will require methods for environmental, economic and social evaluation. While LCA seems generally accepted, and is even standardized to some degree (see Section 1), work on the economic and social methodologies remains to be formalized.

3.1 Economic aspects: Life cycle costing

Life cycle costing (LCC), with some roots in the evaluation of acquisitions of high cost military equipment (Sherif and Kolarik 1981), has recently emerged as a likely concept and tool for the second dimension of sustainability (Klöpffer 2003). Key issues include the use of the same system boundaries and functional units as in LCA. LCC within the sustainability framework, i.e. in combination with LCA and social assessments can be defined as follows (Rebitzer and Hunkeler 2003):

LCC is an assessment of all costs associated with the life cycle of a product that are directly covered by any one or more of the actors in the product life cycle (supplier, producer, user/consumer, end-of-life actor), with complimentary inclusion of externalities that are anticipated to be internalized in the decision-relevant future.

This definition has been adopted by SETAC-Europe's working group on LCC, whose charge is expected to being finalized in the beginning of 2006 with a first comprehensive overview of specific approaches and recommendations for assessing the economic life cycle of products within sustainability. Although quite a bit of progress has been made, consensus on externalities and if/how they should be covered, as well as discounting of future costs and revenues, remains to be established. The former issue, concerning predominantly the scope of LCC and the definition of interfaces to LCA and social assessments, including concerns of double-counting, seems to be relatively easy to solve, based on the broad consensus that one needs a clear distinction between the three pillars of sustainability. The latter is more critical as long term effects are essentially reduced to zero with any discount rate significantly above 0%. However, economic realities require mid-term interest rates, typically in the 2–20% range, over 5–30 years, as a function of the product life and the required assets. Likely, one has to find a two-step procedure to cover both aspects, based on specific scenarios.

Despite these open issues, it seems that LCC is on a, relatively fast, track to being established as a tool for the evaluation of the economic implications associated with a product's life cycle. In particular, the parallel application with LCA, utilizing common data and models, provides many synergies and thus enhances the application of life cycle approaches for decision making (Rebitzer 2005). This is a path that has to be continuously followed, possibly also including standardization initiatives, in order to achieve a status similar to that of LCA.

3.2 Social aspects

Though there has been research on social life cycle approaches and interrelations to LCA already in the 1990s (Brien et al. 1996), this subject has not significantly advanced over the past decade. Recently, however, the social axis has re-gained attention, through the UNEP/SETAC Life Cycle Initiative (UNEP/SETAC 2005) and publications in this and other journals (see e.g. Klöpffer 2003, Dreyer at al. 2005). It is clear that the assessment of the social aspects of all elements of the life cycle is a critical future issue for life cycle approaches in general. Evidence for this is for example the shift from environmental to sustainability reporting of multinational enterprises or the Millennium Goals of the United Nations (UN 2005).

[3] This somewhat provocative statement should not be misunderstood as a denial for the need to establish the scientific basis via theoretical developments, but rather as a pledge to avoid 'write only' research without aiming to contribute to improvements in sustainability.

The development of the methodological basis for social assessments, however, is in its infancy, far behind LCA and LCC, and probably much more difficult. What does this mean for the future of LCA and the LCA community? From the point of view of the authors of this editorial, the need for a methodological basis for the assessment of social aspects of a product life cycle poses immense opportunities, though also risks: Lessons learnt from the development of LCA should be taken up and the conceptual basis of LCA can probably also be used for social assessments. On the other hand, care has to be taken not to develop this in isolation within the environmental community. For both validity and acceptance it is essential to interact with the social and socio-economic sciences. Similar to the recommendations given for LCC, it seems also highly advisable to clearly define the interfaces to the environmental and economic assessments in order to build an independent dimension of sustainability (one of three). This independence is, in any case, a principle of sustainable development, which aims at balancing environmental, economic, and social considerations (WCED 1987). Tendencies to methodologically integrate all impacts and benefits, may they be environmental, economic, or social, into (environmental) LCA seem to be rather counterproductive in this context.

4 The Future

Summarizing the brief analyses above, it is clear that the future will pose both significant challenges and opportunities for LCA and related life cycle approaches. In the long term it seems essential to have a clearer focus on the applicability of LCA and on enhancing wide-scale implementation (for a further discussion see Heiskanen 2002). The step from theory to practice is a difficult one, though essential if LCA is to distinguish itself from a large set of, otherwise arbitrary, tools. In addition, one should prioritize the development of an accepted and standardized methodology for life cycle costing, a code of practice and an international standard for the framework. LCC needs to define specific system boundaries, and functional units, compatible with LCA, and make a clear statement on externalities. LCC needs, also, to make a strong set of rules on normalization, much akin to the discussion which took place in the 1990s in regards to impact assessment.

The LCA community can also lead the way forward in implementing standards, metrics, procedures and inventory data for the social dimension of sustainability, while cooperating strongly with other fields. The position of LCA experts in developing the economic dimension is an example of how such a debate can, rather rapidly, turn into a decision-oriented methodology with a high degree of acceptance. For life cycle assessment to provide a means forward for social assessments, it will have to establish a list of accepted 'end point' categories and learn from the debate that raged in regard to impact assessment and the weighting of impacts a decade ago. At present, the list of social indicators is long, over two hundred (Steen et al. 2005). To be manageable, this list needs to be validated, shortened and, quite likely, not combined with environmental and economic aspects. LCA has a history in accounting for the complexities in the numerical analysis of multi-faceted problems and this strength should see it well in the development of a societal axis of sustainability. Qualitative approaches should also not be neglected, both in social assessments as well as in LCC, for those areas where quantification is not (yet) possible. The use of similar boundaries and functional units, as in LCA and LCC, should help societal assessment in terms of computability and comparability.

We, as scientists, developers and practitioners, should challenge ourselves to have international standards for life cycle costing and social assessment in place before 2015.

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[See Ref. Dreyer et al. 2005]

A Framework for Social Life Cycle Impact Assessment

Louise Camilla Dreyer[1 2]*, Michael Z. Hauschild[1] and Jens Schierbeck[3]

[1] Technical University of Denmark (DTU), Department of Manufacturing Engineering and Management (IPL), Section for Innovation and Sustainability, Produktionstorvet Bygning 424, 2800 Lyngby, Denmark
[2] Brødrene Hartmann A/S, Corporate Sustainable Development, Klampenborgvej 203, 2800 Lyngby, Denmark
[3] JPS management, Øverødvej 48, 2840 Holte, Denmark

*** Corresponding author** (lcd@hartmann.dk)

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Goal, Scope and Background. To enhance the use of life cycle assessment (LCA) as a tool in business decision-making, a methodology for Social life cycle impact assessment (LCIA) is being developed. Social LCA aims at facilitating companies to conduct business in a socially responsible manner by providing information about the potential social impacts on people caused by the activities in the life cycle of their product. The development of the methodology has been guided by a business perspective accepting that companies, on the one hand, have responsibility for the people affected by their business activities, but, on the other hand, must also be able to compete and make profit in order to survive in the marketplace.

Methods. A combined, bottom-up and top-down approach has been taken in the development of the Social LCIA. Universal consensus documents regarding social issues as well as consideration for the specific business context of companies has guided the determination of damage categories, impact categories and category indicators.

Results, Discussion, and Conclusion. The main results are the following: (1) Impacts on people are naturally related to the conduct of the companies engaged in the life cycle rather than to the individual industrial processes, as is the case in Environmental LCA. Inventory analysis is therefore focused on the conduct of the companies engaged in the life cycle. A consequence of this view is that a key must be determined for relating the social profiles of the companies along the life cycle to the product. This need is not present in Environmental LCA, where we base the connection on the physical link which exists between process and product. (2) Boundaries of the product system are determined with respect to the influence that the product manufacturer exerts over the activities in the product chain. (3) A two-layer Social LCA method with an optional and an obligatory set of impact categories is suggested to ensure both societal and company relevance of the method. The obligatory set of impact categories encompasses the minimum expectations to a company conducting responsible business. (4) A new area of protection, *Human dignity and Well-being*, is defined and used to guide the modelling of impact chains. (5) The Universal Declaration of Human Rights serves as normative basis for Social LCA, together with local or country norms based on socio-economic development goals of individual countries. The International Labour Organisation's Conventions and Recommendations, and the Tripartite Declaration of Principles concerning Multinational Enterprises and Social Policy, support development of the impact pathway top-down, starting from the normative basis. (6) The obligatory part of Social LCA addresses the main stakeholder groups, employees, local community and society. – Social LCA is still in its infancy and a number of further research tasks within this new area are identified.

Gerald Rebitzer receiving his thesis from Prof. Olivier Jolliet, with congratulations from David Hunkeler

Doctoral Thesis of Gerald Rebitzer, July 8th, 2005

Enhancing the Application Efficiency of Life Cycle Assessment for Industrial Uses

Walter Klöpffer and David Hunkeler had the pleasure of being members of the jury of the Doctoral Thesis of Gerald Rebitzer, along with Stephan Seuring and his advisor Olivier Jolliet. We found Gerald to have contributed very important concepts in regards to the theory of LCA as well as its practical application. Gerald's work on thresholds should be well cited and his contribution to the development of modular LCA is important. Gerald's approaches are simplified, and valid, and his case studies on material options are extremely well done, integrating LC Costing and LCIA. We give Gerald our heartfelt congratulations.

Walter Klöpffer and David Hunkeler